The Sidereal Messenger.

CONDUCTED BY WM. W. PAYNE,

Director of Carleton College Observatory.

NOVEMBER, 1887.

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Thou Lord in the beginning hast laid the foundation of the earth, and the heavens are the works of thy hands.

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The Messenger will be published monthly except for July and August.

Subscription price per year (ten numbers) $2.00.

Communications should be addressed to the Editor, Northfield, Minn.

NORTHFIELD, MINN.

CARLETON COLLEGE OBSERVATORY.

Entered at the Post Office at Northfield, Minn., and admitted for transmission through the mails at second class rates.

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CONDUCTED BY WM. W. PAYNE,

Director of Carleton College Observatory, Northfield, Minnesota.

VOL. 6, NO. 9. NOVEMBER, 1887. WHOLE NO. 59.

THE REJECTION OF DISCORDANT OBSERVATIONS.

ASAPH HALL.*

For the MESSENGER.

The question, what shall be done with observations that present large discordances from a mean value, is one that will continue to perplex investigators for a long time. The founders of the method of least squares have called attention to the fact that the law of error which is derived from the assumption of the arithmetical mean as the most probable value is not rigorously correct. This is expressly stated by Gauss in his Theoria Motus; and for a finite number of observations, a condition which always holds in practice, similar statements have been made by Laplace and Poisson, to whom we are indebted for the most general investigations of the law of error. The rule of the arithmetical mean is justified on the ground that it corresponds to common sense and universal practice. Criticisms and improvements of the method of least squares, therefore, will always be in order, whether they pertain to modifications in the law of error itself, or simply propose to change some of the constants into more general functions to be determined to suit special cases. Let us look at some of the results obtained by means of the methods proposed for dealing with this difficult question.

PEIRCE'S CRITERION.

This criterion was given by Professor Benjamin Peirce in *Gould's Astronomical Journal*, vol. 2, p. 161. Though warmly recommended by several eminent American astronomers, this

* U. S. Naval Observatory, Washington, D. C

criterion has never come into general use, but it has been employed for a long time by Mr. C. A. Schott, chief of the computing division of the United States Coast and Geodetic Survey. Such a practical recommendation is important, even though Mr. Schott qualifies it by the warning that care must be taken in its use, since sometimes this criterion "cuts too deep." Professor Peirce applied his criterion to two examples. The first is that of thirty observations of the semi-diameter of Venus made with the mural circle of the Naval Observatory in 1846. After a reduction of these observations Professor Peirce finds the probable error of a single determination to be $\pm 0.28''$. His criterion rejects no observation. The second example is that of fifteen observations of the same semi-diameter made with the meridian circle of the Naval Observatory in the same year. In this case the probable error of a single determination is $\pm 0.39''$; and two observations giving the residuals $+1.01''$, and $-1.40''$, are rejected by the criterion. After this rejection the probable error of a single determination is $\pm 0.21''$. This diminution of the probable error is a suspicious circumstance. It is well known that observations with the mural circle were more accurate than those made with the old meridian circle; and the values of the probable errors found before the criterion was applied correspond very well to the relative accuracy given by a large number of observations. It is perhaps from such consideration as this, and from noticing how an apparent accuracy may be given to inferior work, that this criterion has been prevented from coming into general use. Since this second example is often referred to by writers on this subject it may be well to state, though it does not affect the argument, that the records show that not one of the fifteen observations was made by Lieutenant Herndon.

STONE'S CRITERION.

Mr. E. J. Stone, the present Radcliffe observer, does not accept the criterion of Professor Peirce, and in the *Monthly Notices* of the Royal Astronomical Society, vol. 28, p. 165, he gives a rule of his own. If a given observer makes one careless observation in 500, Mr. Stone finds that the limit of rejection is

about five times the probable error of an observation. Thus if the probable error is $\pm 0.48''$, and an observation gives the residual $2.5''$, this observation should be rejected. This is a very simple criterion, and can be applied easily. We infer from the method of least squares that in a thousand observations there will be but a single error greater than five times the probable error. The application of Mr. Stone's criterion, therefore, could not do much harm, and yet I think astronomers would hesitate in applying it. The probable error $\pm 0.48''$ is about that of an observation with the common meridian circle, and unfortunately residuals as great as $2.5''$ are still apt to occur in this kind of work.

De MORGAN'S METHOD.

Professor Augustus De Morgan proposed a method of weighting observations by means of approximate solutions until the assumed and deduced weights agree. Not having seen De Morgan's exposition of his own method I cannot speak of it with accuracy. It has been referred to as a method of meeting the difficulty of discordant observations by diminishing their weight. The weight depends on the probable error, which should be found from the whole series of observations. If the discordant observations are so managed as to be given arbitrarily a very small weight this process would become equivalent to a rejection. The criteria of Peirce and Stone seem to meet the question more fairly.

Besides these criteria two other methods have been proposed for use in the discussion of observations. The first is a proposal to change the law of error which is adopted in the method of least squares for one in which the first power of the error enters. In his earlier investigations Laplace adopted a law of this kind, but he soon discarded it for the one now used. It is true that the strict method of least squares sometimes leads to great labor of computation, and it may be well in some cases to shorten the work by grouping the observations. This can be done without changing the law of error. Again it may be sufficient for some observations to reduce the equations of condition by the old method of making the sign

of similar terms the same, then adding all the equations, and thus deducing a set of normal equations. This will generally give a good result, but if the observations are accurate it is better to spend a little more labor on them.

Another method has been proposed for the treatment of discordant observations in which the law of error assumed in the method of least squares is retained, but the measure of precision is made a function of several unknown quantities, which are to be determined from the residuals found from a preliminary comparison. There can be no doubt that in a given series of observations the measure of precision is not a constant, as is commonly assumed; and it must certainly be subject to small fluctuations dependent on the condition of the observer and his instrument. It might vary with the daily allowance of food and stimulant provided for the observer. Now it seems probable that if we split an assumed constant into several parts, and attach various meanings to them we shall be able to represent the observations more accurately. In the case of the fifteen observations of the semi-diameter of Venus observed in 1846 such a process would permit us to represent the residuals very well. But into how many parts shall we divide the measure of precision; two, five, or fifteen? We might assume a periodical series and satisfy the residuals exactly; but after all the labor one cannot avoid the suspicion that this procedure is nothing more than an attempt to conceal ignorance under mathematical forms.

The question recurs whether there is any advantage in the discussion of observations by means of these rules over the judgment of an experienced investigator. I think the reply must be in the negative. For most cases of discordance that occur in practical astronomy the judgment of an experienced astronomer will be better than any arbitrary rule. Take for example the observations of a solar eclipse, or the transit of one of the interior planets. For several reasons such observations are liable to large errors. The heat of the sun and its effect on the eye and instrument in confusing the images, and the slow motion of the planet, make a little maladjustment of

the instrument capable of producing errors of 20 or 30 seconds of time. The usual result is that many observations are made by inexperienced observers, and sometimes by those who have no good means of knowing their local time. Now an astronomer of experience will extract a better result from these observations than can be found by any set of fixed rules. His methods may seem arbitrary, but he is the last and best resort. Of course in cases where each observer has made a considerable number of observations the probable errors of the different series will furnish the combination weights.

There is one peculiarity of observations which may seem to partake of a discordant nature that should not be lost sight of. This is what Mr. M. H. Doolittle of the Coast Survey office calls their *instructive* character. Observations should not be rejected until they have been carefully scanned, since they may contain important information. Several inequalities in the motions of the planets and the moon have been discovered by apparently discordant observations, and although satisfied for a time by empirical formulæ they have frequently led to theoretical explanation. We sometimes see careful observations in astronomy that evidently contain systematic errors. These errors are commonly included under the vague terms of "flexure" and "refraction;" and generally they may be taken as good evidence that the astronomer has not become master of his instrument. Such results should spur him on to further investigation.

The method of least squares is a beautiful application of the theory of probabilities, and it is the best method of treating observations that has been devised. It is an instrument, and observers should become familiar with it and learn to apply it correctly. It was never designed, as Delambre sarcastically remarks, to make good observations out of poor ones, but it gives the best result fron the given data.

October 6, 1887.

THE NEW REPSOLD MERIDIAN CIRCLE OF CARLETON COLLEGE OBSERVATORY.

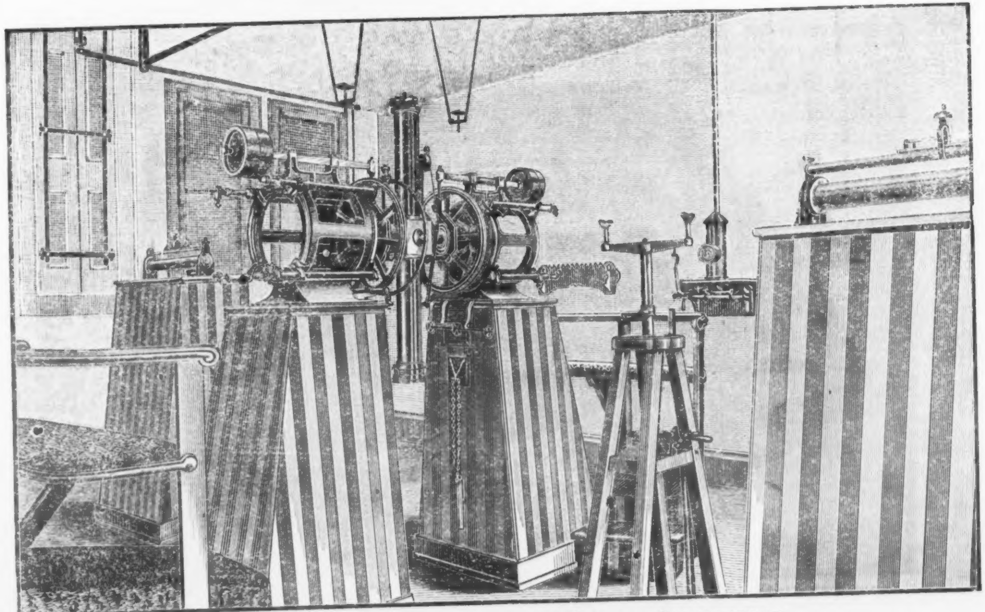
THE EDITOR.

The new Meridian Circle, now mounted in the new astronomical observatory of Carleton College, Northfield, Minnesota, was made by Messrs. A. Repsold and Sons, Hamburg, Germany. It was about two years in progress of construction, being completed in the summer of 1885. It was received late the same year and the erection of the new building for the observatory began in the summer of 1886, and it is not yet fully completed, though it has been occupied since August last.

For the purchase money and the cost of mounting the new instrument the observatory is indebted to James J. Hill, President of the St. Paul, Minneapolis and Manitoba Railway Co., whose generous gift of $5,000 has proved amply sufficient. While conversing with Mr. Hill concerning the projected lines of scientific research before the new observatory of Carleton College, we were delighted to recognize his intelligent interest and quick insight in, and ready comprehension of, present phases of scientific thought and the advantages of the best and most powerful modern appliances in promoting original investigation. Though Mr. Hill is well known for his many gifts to science and for the public good generally, it is all done so unostentatiously that no one competent to judge can know the facts without true admiration.

The east wing of the observatory is devoted entirely to the Meridian Circle. It is 27 feet 6 inches north and south, and 22 feet 10 inches east and west, inside measure. From floor to ceiling it is 12 feet 2 inches. The four piers, seen in the accompanying cut, stand on three separate foundations. All have good footing 10 feet below the floor in coarse gravel. They are built of limestone and the best cement. Above the floor each of the piers is covered with heavy felting and finished outside with cherry and ash. At the base below the floor the respective sizes of the piers are as follows:

Central one is 9 feet by 3 feet 6 inches.



Meridian Circle Room, Carleton College Observatory.

The bases of the north and south collimator piers are equal, being 4 feet by 3 feet 6 inches. The cellar is the same size as room above, with good wall 18 inches thick on all sides, with one inside entrance and two outside ventillating windows. The depth of cellar is 8 feet.

The north and south openings of the observing room for the meridian are 26 inches wide, and provided each with two shutters securely held in place by the iron adjustable frame, commonly used in observatories for this purpose, and plainly shown in the cut. There are two doors for the meridian opening in the roof, each about 14 feet long and 3 feet wide outside. These doors are opened easily and quickly by levers of steel 10 feet long and 2 inches in diameter, weighing each about 80 lbs. The doors are hinged to the roof and their weight is partly counterpoised by the weight of the levers so that a pull of 35 lbs is sufficient to open them under any circumstances if clear of snow or sleet. Their operation is very satisfactory.

By referring to the cut the collimators and the mode of mounting them will be easily understood. The glass cases which cover the telescopes have been removed and the levels put in place, to show their relation to the collimators. Their apparent unequal size is due, of course, to perspective, the point of view being the southwest corner of the observing room. The collimating telescopes are 33 inches long, with objectives 2.64 inches in diameter, and the main telescope between the middle piers (in vertical position) is 58 inches long. The object glass was made by A. Clark & Sons, Cambridgeport, Mass., and has a clear aperture of 4.80 inches and a focal length of 57.5 inches. The diameter of the graduated portion of the circles is 21.8 inches. One circle is movable, and is divided to degrees, the other is fixed and divided to two minutes of arc. The circles are each provided with four microscopes having micrometers which measure directly to one second of arc and which are adjusted closely enough to detect an error of one-tenth of a second of arc. These microscopes have already been placed symmetrically on the circular iron frame as is desirable to read the circles properly.

The micrometer of the telescope is provided with a spider-line reticle which contains seven groups of wires, numbering 27 in all. One revolution of the right ascension micrometer screw has been carefully determined and is 64.12″. The value of the micrometer screw in declination is yet only approximately ascertained. The measure of both micrometer screws for the collimators is the same, and was determined by the aid of the wire intervals of the transit instrument. Value of one revolution is 54.90″.

The wire intervals of the transit instrument have all been determined by transits of circumpolar stars, and the central groups also by micrometer measurement. These fixed wires all seem to be well in place except one.

In this connection, it may be well to mention a little experience that we have had, in the displacement of these delicate spider threads. After using the micrometer a short time, the motion of the screw was not entirely free through the run of the field. The head was carefully taken apart, and the movable frame of the reticle adjusted to easy motion. In doing this, in some unaccountable way, two of the nearest parallel fixed threads were thrown into the same groove, and were very closely side by side. To replace them without destruction seemed at first a problem of some difficulty. A pair of tweezers, with a hair about one inch long, was the instrument chosen for the work. In the steady hand of Dr. Wilson, this device accomplished the work in a very few minutes satisfactorily. The hair was also used to remove from the other threads particles of dust which had lodged upon them.

One division of the hanging level has been found approximately. The instrument has four eye-pieces which have been measured by three different observers with the following results for magnifying power:

I = 91.
II = 133.
III = 195.
IV = 268.
Diagonal V = 202.

The magnifying power of the eye-pieces of the collimators is 100, and the same for each instrument.

Observations for the latitude of the observatory have already begun and the work on twenty stars, on different nights, is yet unreduced. The work for the Meridian Circle in the near future, besides the study of the errors of the instrument, will be, observations for latitude, time, azimuth; comparison stars for comets; comparison stars used by Professor Stone, of Leander McCormack Observatory, in his work on the places of nebulæ, and a select list of stars from 4th to 8th magnitude for geodetic purposes.

Dr. H. C. Wilson is in charge of the Meridian Circle, and he is making good progress, as the preceding record shows, for a period of less than four weeks' time.

ON THE RELATIVE MOTION OF THE EARTH AND OF THE LUMINIFEROUS ETHER.

ALBERT A. MICHELSON AND EDWARD W. MORLEY.

(Abstract.)

To explain astronomical aberration according to the undulatory theory of light, Fresnel made two suppositions: First, that the ether is at rest except in the interior of transparent media; and secondly, that in such media it is moving with a velocity less than that of the medium in the ratio $\frac{n^2-1}{n^2}$ where n is the index of refraction. The second hypothesis is already established; the authors have now submitted the first to the test of experiment, by the method proposed and executed by Michelson in 1881, so modifying the scale of the experiment and the mounting of the apparatus as to obtain decisive results.

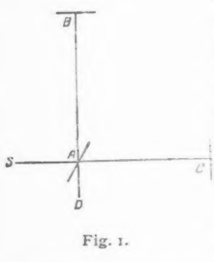


Fig. 1.

Let light from s be partly reflected to b and partly transmitted to c, and be returned by mirrors at b and c; par he returning light will unite along ad, and, if the two paths are equal, will produce interference. If now,

the ether being at rest, the apparatus moves in the direction *sc* with the orbital velocity of the earth, the directions and distances described by the rays will be altered; if we put D for the distance *ab*, and v and V for the velocities of the earth and of light, we shall find the difference of path to be $D\frac{v^2}{V^2}$. If the apparatus be now rotated so that *ab* is in the direction of the orbital motion of the earth, the difference will be in the opposite direction, and the displacement to be observed will therefore be $2D\frac{v^2}{V^2}$.

In the experiment of 1881, D was such that the displacement according to theory would be 0.04 wave length; in the present case, D was, by repeated reflections, made about ten times as large. The former apparatus was extremely sensitive to vibrations and suffered distortion during the rotation; these difficulties have now been entirely overcome by mounting the apparatus on a massive stone floating on mercury.

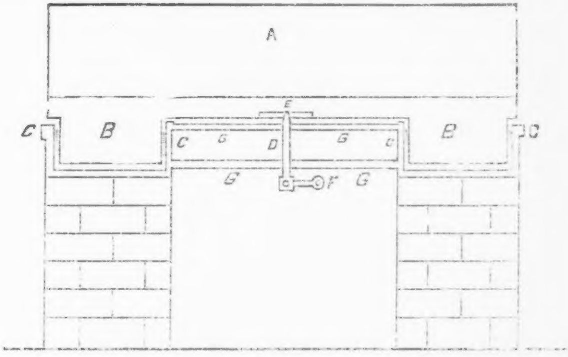


Fig. 2.

a is a stone 1.5 metres square, and 3 decimetres thick. *bb* is an annular wooden float. *cc* is an annular trough containing mercury; between the float and the trough is a clearance of one centimetre. A pin *d* can be pushed into a socket *e* so as

to keep the float concentric with the trough ; the pin bears no part of the weight.

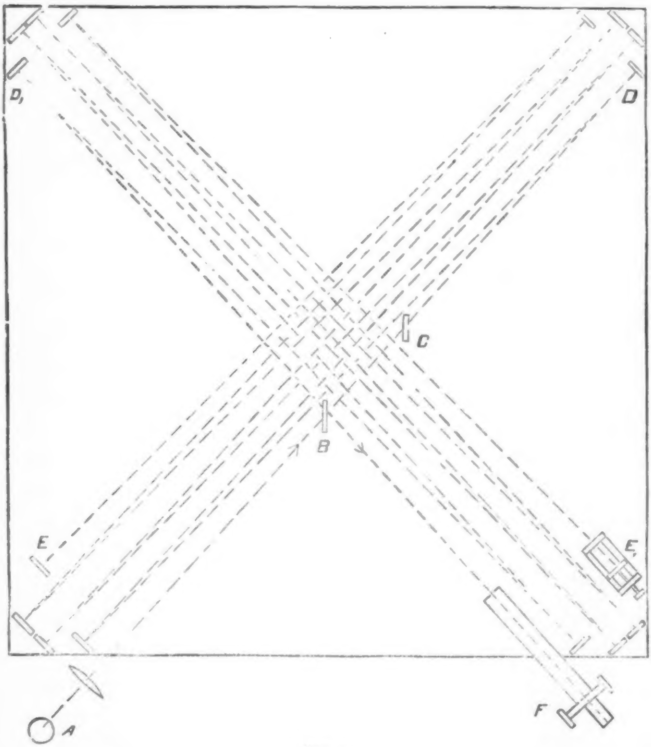


Fig. 3.

At each corner of the stone are four plane mirrors, *e*, *d*, of speculum metal. *b* and *c* are plane parallel glasses. Light from an Argand burner at *a* divides at *b*, follows the paths indicated, and reaches the observing telescope *f*.

The mirrors having been adjusted so that both rays entered the telescope, the lengths of the two paths were made nearly equal by measurement and by moving the mirror *e* which

could be moved in the direction of its normal, keeping very accurately parallel to its former plane. The telescope being adjusted to distinct vision of the source, the two images were made to coincide. Then the telescope being adjusted to distinct vision of the expected interference fringes, sodium light was substituted for white light, and the interference fringes were made as clear as possible by adjustment of the mirror *e*. White light being restored, *e* was slowly moved in the direction of its normal till the fringes reappeared in white light, when they were adjusted to a convenient width and position and the apparatus was ready for observation.

While the apparatus was revolving once in about six minutes, the wire of the micrometer was set on the clearest fringe at the moment of passing one of the sixteen equi-distant marks on the iron trough ; the readings were continued for six revolutions.

The following are the means of three such sets of readings made at noon on three days and of three sets of readings made at six hours after noon on three days. The numbers are wave lengths, and are corrected for linear variations.

Marks	16	1	2	3	4	5	6	7	8
Noon	0.00	− 0.07	+ 0.02	0.00	− 0.01	+ 0.13	+ 0.23	+ 0.16	0.00
Evening	0.00	+ 0.06	− 0.02	+ 0.07	+ 0.05	+ 0.16	+ 0.13	+ 0.03	0.00

These means are plotted in the following figure :

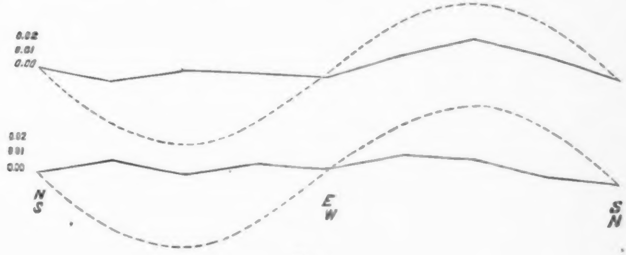


Fig. 4.

The upper curve represents the noon observations and the lower those at evening. The dotted curves represent *one-eighth*

of the theoretical displacement. The actual displacement, it seems fair to conclude, was certainly not one-twentieth, and probably not one-fortieth, of the theoretical. The displacement varies as the square of the velocity ; therefore the relative velocity of the earth and the luminiferous ether was certainly not one-fourth and probably not one-sixth of the orbital velocity of the earth.

It is of course possible that the orbital velocity of the earth at the time of the experiment was equal and opposite to that of the solar system through space. Measurements will therefore be repeated at proper intervals.

A NEW MODE OF DETERMINING THE CONSTANTS OF REFRACTION AND ABERRATION.

GEORGE C. COMSTOCK.*

In a series of papers published during the past two years in the *Comtes Rendus*, M. Loewy has suggested the introduction into practical astronomy of a new instrument and has worked out in detail its application to the solution of two important problems of spherical astronomy, the determination of the so-called constants of refraction and aberration.

The fundamental idea upon which the proposed methods of research are based is the superior accuracy of differential as compared with absolute measurements. The determination of the astronomical refraction by the methods hitherto in use furnishes an excellent example of the difficulties attending investigations of the latter class. We have here to determine the absolute declinations of a group of circumpolar stars from observations made at their upper transits over the meridian and the declinations of the same stars from observations made at their lower transits. The value of the refraction depends ultimately upon the difference of the declinations thus determined. Consecutive observations of the same star are thus separated by an interval of at least twelve hours, frequently by a much longer one, and the astronomer engaged in a research of this kind has to fear not only the instrumental sources of

* Director of Washburn Observatory, Madison, Wis.

error which affect a single observation, such as flexure, division errors, irregularities of micrometer screws, etc., but also the change in instrumental constants and in exterior surroundings during the interval elapsed between the observations. All these sources of error must be examined at an enormous expenditure of time and labor, their influence upon the resulting declinations determined, and when this has been done there remains the certainty that whatever instrumental error rests undetected has gone into the quantity to be determined and thus tends to vitiate it.

Suppose it possible to make the required observations simultaneously and to make them in such a manner that whatever error affects one observation shall affect the others in the same way, then when differences are taken the result is absolutely free from the errors which before were the chief source of uncertainty in the determination. This, then, is the problem which M. Loewy has proposed to himself and has solved: To devise a method by which the refraction can be so determined that the resulting value shall not be appreciably affected by instrumental errors.

The effect of refraction being to apparently displace all stars from their true positions toward the zenith it follows that the apparent angular distance between any two stars is affected by the refraction, and the amount by which it is so affected varies from hour to hour on account of the changed positions of the stars relative to the zenith. Thus, if one of the stars is in the zenith and the other in the horizon the distance is diminished by the whole amount of the refraction at the horizon. If the same two stars are by the diurnal motion brought into a position in which they are at equal distances from the zenith their apparent distance from each other will still be affected by the refraction, but the effect in this position will be much less than before. The exact amount of the effect in every case can be stated mathematically in terms of a certain quantity called the constant of refraction, and it is this quantity which is to be determined. Suppose the apparent distance of the pair of stars to be measured in each of two positions.

Each observation will furnish an equation containing two unknown quantities, the true angular distance of the stars and the amount of the refraction expressed in terms of the constant of refraction, and by the solution of the two equations we may determine the quantities required. Thus, if k denote the constant of refraction, ak and bk the effect of refraction upon the apparent distance of the stars at the times of the first and second observations respectively, D the true distance between the stars as it would appear if there were no refraction, and D_1 and D_2 the measured distances between the stars; we have the equations

First observation, $D_1 = D + ak$
Second observation, $D_2 = D + bk$

by combining which we find, $k = \dfrac{D_2 - D_1}{b - a}$

We have here determined k by a method which involves only the numerical cöefficients b and a, whose values can be computed from the known positions of the stars, and the quantity $D_2 - D_1$ which is the difference between the results of two observations made at an interval of four or five hours.

Thus far, however, but little that is new has been developed. If we attempt to carry out the plan thus indicated and to measure the distances D_1 and D_2 with any of the instruments in ordinary use we shall find since the positions of the stars at the two times are quite different, that the observations will be affected with different errors and the difference $D_2 - D_1$ will not be free from their effects but may be influenced by them to an extent equal to the sum of the two separate errors. The merit of M. Loewy's method consists in a new mode of making the observations and in the proof that when so made the results are free from the effects of instrumental errors.

In front of the objective of an equatorially mounted telescope imagine a prism with silvered faces, placed as in the accompanying figure, in which the broken lines represent the paths of rays of light coming from two stars and

reflected from the surfaces of the prism so that images of the stars are formed at the focus of the telescope. It is evident that by choosing a proper value for the angle of the prism, the images of any two stars may be brought simultaneously into the field of view of the telescope and that the distance between the images may be measured with a micrometer. It follows from simple optical principles that the angular distance of the two stars is equal to twice the angle of the prism plus the measured distance between the images, so that the measurement of the large angular distance between the stars is reduced to the measurement of a small distance with a micrometer, an observation which can be made with great precision. To know the absolute distance between the stars, however, we still need to know the angle of the prism, but fortunately the determination of the constant of refraction, as has already been shown, does not require us to know the angle between the stars but only the variation of that angle, $D_2 - D_1$, due to the changed positions of the stars relative to the zenith, and this variation of the angle is equal to the difference of the micrometer measurements at the two times.

Let us recur now to the subject of instrumental errors and see how the method thus indicated is free from them. It is evident that between the two observations of the pair of stars whose distance apart is to be measured, several hours must elapse, and that the telescope must be turned to different parts of the heavens in making the observations, and it appears at first sight that the turning of the telescope into a new position, combined with the changed effect of gravity and possible variations of temperature, must produce some change in the position of the prism relative to the telescope which will alter the position of the images in the field of view and give rise to errors absolutely fatal to the accuracy of the results. But such is not the case. Any motion whatever of the prism relative to the telescope can be resolved into a motion of translation of the whole prism, and a motion of rotation about one or more of a set of three axes taken at right angles to each other. A motion of translation of the prism cannot affect the

distance of the images from each other, unless the objective of the telescope is grossly defective and M. Loewy has shown by an elegant mathematical analysis that a small rotation of the prism about any axis, at right angles to the axis of the telescope, can have no appreciable effect upon the distance of the images in the field of view, its only effect being to displace both images in the same direction and by the same amount. The only remaining motion to consider is a rotation about the axis of the telescope itself. This does produce a change in the relative position of the images, but this very rotation may be made use of to determine the position in the field of view of the plane passing through the two stars and the eye of the observer. The projection upon this plane of the distance between the stars is unaffected by any small rotation of the prism whatever, and in the observations it is this projection of the distance between the images, and not the distance itself, which is to be measured, *i. e.*, this is the quantity which above we called D_1 and D_2.

Another source of error still remains to be noted. It is possible that the angle of the prism may be altered by change of temperature, or other causes, in the interval between the two observations and a change of this kind will appear with its full value in $D_2—D_1$; but even this source of error is eliminated by observing two pairs of stars so situated that if this error makes $D_2—D_1$ too great in one case, it will make it too small in the other, and will thus disappear from the mean of the two determinations. A determination of the constant of refraction is thus obtained from two observations made within a few hours of each other by the same observer with the same telescope, each observation consisting in measuring with a micrometer the distance between two stars which appear side by side in the same field of view.

It is not, however, to be supposed that the method of research thus suggested is in itself so perfect as to preclude the necessity for care and skill in the execution of the observations. As here presented it is given in its barest outlines only, and numerous precautions to be observed will suggest

themselves to the mind of any one familiar with the art of observing, but their exposition does not fall within the scope of this article.

We have thus far treated M. Loewy's method as applied to the determination of the refraction only, but he has published an elaborate series of papers upon its application to the determination of the constant of aberration to which it is equally well adapted. The effect of the annual aberration is to displace all stars toward the point to which the motion of the earth in its orbit is at any moment directed. The amount of the displacement for any star can be expressed in terms of the angular distance of the star from this point, and of a certain quantity called the constant of aberration. The apparent distance of two stars is therefore affected by the aberration in much the same way, although not according to the same law, as in the case of the refraction, and as the point toward which the earth is moving changes constantly and runs through its complete cycle of 360° in a year, it follows that the effect of the aberration upon the apparent distances of two stars will vary from a maximum to a minimum in the period of six months, and if the distance between two stars properly chosen, is measured at the times when aberration has its maximum and its minimum effect, we may obtain from the variation in the distance the value of the constant of aberration.

Let us examine a little more closely some of the theoretical considerations involved in a determination of this constant. If we put

g = The constant of aberration,
L = The longitude of the sun.
D = The true angular distance between any two stars.
λ and β = The longitude and latitude of the middle point of the arc D.
dD = The effect of aberration upon the length of D.

then we shall have

$$dD = -2g \sin\frac{D}{2} \cos\beta \cos(\lambda - L)$$

a formula which will enable us to fix the conditions most favorable to a determination of g.

It will obviously be advantageous to make the variations of the distance, dD, as great as possible hence β must differ but little from $0°$, *i. e.*, the stars must be so selected that the arc joining them will be bisected by the ecliptic. It would also seem advantageous to make the distance D nearly equal to $180°$ but for reasons to be given hereafter it will be best to make D as nearly as possible $120°$. Owing to the sun's motion in longitude the angle $\lambda - L$ varies continuously throughout the year, assuming all values from $0°$ to $360°$. If the distance between the stars be measured when $L = \lambda - 90°$ and again when $L = \lambda + 90°$, that is, after an interval of six months, we shall have from the two observations the two equations :

$$D_1 = D - 2g \sin \frac{D}{2} \cos \beta$$

$$D_2 = D + 2g \sin \frac{D}{2} \cos \beta, \text{ whence}$$

$$g = \frac{D_2 - D_1}{4 \sin \frac{D}{2} \cos \beta}$$

or if we assume $D = 120°$, $\beta = 0°$, then

$$g = 0.2887\,(D_2 - D_1)$$

It thus appears that whatever error of any kind may be committed in measuring $D_2 - D_1$ will be largely diminished by multiplying the observed quantity by a cöefficient less than 0.3.

It is obvious from the character of the observations to be made that the method of M. Loewy is as applicable to this case as to the refraction, but with this difference, that in a determination of the constant of aberration the two observations instead of being made within a few hours of each other are separated by an interval of several months, and the danger of a change in the angle of the prism between the observations is thereby greatly increased. To eliminate error from this source M. Loewy points out that the aberration has no effect upon the distance between two stars which have the same latitude and whose longitudes differ by $180°$, and he recommends

that such a pair of stars be measured in connection with a pair so situated that the aberration may have its maximum effect. By combining the two sets of observation both the aberration and the change in the angle of the prism, if one has occurred, may be determined. A more radical cure for this source of error would seem to be the use of a prism each of whose angles is, as near as may be, 60°. If the distance of the stars be measured with each angle of the prism and the mean of the three results taken this must be independent of any change in the angles of the prism, since from geometrical considerations the mean of the three angles must always be exactly 60°. It is even possible to so arrange the prism that a deformation of its faces, from planes into surfaces slightly curved, will have no systematic effect upon the observations. We thus obtain not only a measure of the change of distance of the stars, but also a measurement of the absolute distance at the instant of observation, a quantity which may be made very useful for other purposes. If such a prism is used, the distance between the stars must, of course, differ but little from 120° and it is for this reason that that distance was suggested above.

The mechanical problem of supporting a prism in front of the objective of a telescope in such a manner as to satisfy all the requirements of this method, appears not yet to have been solved, and an opportunity is here afforded the amateur astronomer of mechanical talent, to make an important contribution to the progress of astronomy by devising a mounting suitable for this purpose. The principal requirements to be satisfied are: The mounting must be light and rigid. The prism must rotate freely about the line of sight of the telescope. Some provision must be made for recording the position of the prism. The prism must be so supported that each of its angles can be used. Adjustments must be provided whereby the prism can be placed symmetrically in front of the objective. All manipulations of the prism should be made from the eye-end of the telescope. Suggestions as to the way in which these conditions may be realized mechanically will be very glad received by the author of this article.

EDITORIAL NOTES.

The subscription price of the MESSENGER for 1888 will be $2 per year as usual, if paid in advance; if later, $2.50. The price is so low, in view of the kind and the amount of matter published, that prepayment is an important condition.

Foreign subscribers, and such only, are requested to draw money orders for payment of subscription on the post office of St. Paul, Minnesota. Collection on any other money order office causes delay and expense.

J. A. Brashear's Work-Shop.—Rarely in our lives have we spent a more enjoyable, or a more profitable, day than that given to a visit at the shops of Mr. J. A. Brashear, on Observatory Hill, in Allegheny City, Pa. The commodious rooms of the new shop, already well filled with fine machinery for the work of mounting telescopes, the apparatus for grinding and polishing plane and curved surfaces, and the arrangements, now in use, for testing finished surfaces are surprisingly complete, and they are another evidence of Mr. Brashear's purpose to do only the best work possible of any kind entrusted to him. We did not before know of his ingenious plans (now well under way) for casting and annealing optical glass. Is there any good reason why Americans should not lead in this industry also?

But to a novice in the practical part of the study of optical surfaces, the most enjoyable things we saw were the tests he made of plane surfaces on glass and mirrors for reflecting telescopes. The fact that the heat of a person's hand, a few inches from a mirror, should, in one minute, so disturb its figure as to make it useless for an hour, and the observer actually see the distortion of the mirror and the heated air curling about the hand, in the face of the mirror, like smoke in a clear sky, was an astonishing sight. It taught a lesson on the delicacy of telescope mirrors not before known. We shall, at another time, speak of other things seen at this place which deserve also special mention.

Carleton College Observatory.—As elsewhere stated, the new Repsold Meridian Circle is now in place, and Dr. H. C. Wilson is busy determining the errors of the instrument preparatory to regular observing work. As fast as results having public interest are determined they will be published in subsequent numbers of this journal.

The 8¼-inch Clark equatorial was dismounted in August last and removed to the new observatory. The lenses and telescope tube were sent to the Clarks for the purpose of fitting to the telescope a new correcting lens for photography. This work will soon be completed, and it is expected that the telescope will be in the new dome ready for use about the middle of the present month.

Messrs. Warner & Swasey, of Cleveland, O., have already put in place, at the new observatory, one of the fine domes which they have contracted to make. It is 17 feet in diameter, and is constructed wholly of steel. Its weight, including the iron truck, is 5,500 lbs., and its operation so easy that no mechanical appliance is needed to rotate it, for a child six years old moves it easily. The other large dome is well under way, but will not be ready for its place until early spring.

Miss Mary E. Byrd, assistant in mathematics and astronomy at Carleton College Observatory for the last four years, has been elected director of the new observatory at Smith College, Northampton, Mass. Miss Byrd's long experience as instructor in collegiate and preparatory schools, and her special studies in the higher mathematics and practical astronomy with instruments, fit her for the new and wider field of labor to which she has been recently called. Many readers of the MESSENGER know also of the value of her articles and will doubtless be favored by more of them. She is now busy at the new observatory of Smith College, putting instruments in order for regular work.

Flamsteed's Stars "Observed but not Existing."—Bailey's account of Flamsteed gives a list of stars under the above title, with the statement, that "the observations appear to be accu-

rately recorded, but which still can not now be found in the heavens." From this fact it was common, subsequently, for astronomers to publish lists of "missing stars," probably from want of agreement of observations. By the more careful work of Bode, Caroline Herschel, Argelander and Bailey these long lists of missing stars were reduced to 22 which had not been accounted for.

In a late memoir for the American National Academy of Sciences, Dr. C. H. F. Peters gives a full and careful explanation of the observations of these 22 stars, and satisfactorily accounts for nearly every one of them. This, of course, refuted the erroneous belief that these stars had been actually extinguished. Dr. Peters suggests, very properly, that a new reduction of Flamsteed's observations is most desirable.

Elements of Comet Barnard (May 12, 1887) from three normal places.—The first normal place was computed from observations as follows:

	Date.		Place.	Local Time. h m s	Observed α'. h m s	Observed δ'. ° ′ ″
1.	June	12.	Greenwich	12 4 25	16 11 2.35	—8 42 17.1
2.	"	13.	Dresden	11 14 45	16 13 6.88	—8 00 49.1
3.	"	13.	Leipzig	12 7 17	16 13 12.74	—7 58 42.3
4.	"	13.	Harvard	16 41 58	16 13 41.93	—7 48 48.8
5.	"	14.	Leipzig	11 54 39	16 15 26.04	—7 14 58.7
6.	"	14.	Harvard	14 41 53	16 15 45.32	—7 8 9.2

The two Harvard Local Times are given in Greenwich Mean Time. From elements communicated by H. Oppenheim in A. N. No. 2791, an ephemeris was computed for dates comprising the observations, to Greenwich 12*h* M. T. There results:

The first normal place,—June 13.5; $\alpha = 16h\ 13m\ 16.62s \pm 0.18s$; $\delta = -7° 57' 10.4'' \pm 3.5''$.

From observations,

7.	June	17.	Hamburg	11 25 4	16 22 8.16	—5 6 1.5
8.	"	17.	Leipzig	12 1 8	16 22 11.57	—5 5 34.2
9.	"	18.	Leipzig	12 23 5	16 24 29.22	—4 23 14.1
10.	"	19.	Leipzig	11 43 8	16 26 40.70	—3 44 3.4
11.	"	19.	Greenwich	11 19 58	16 26 44.10	—3 43 11.8
12.	"	19.	Greenwich	11 26 47	16 26 43.83	—3 42 50.3
13.	"	19.	Hambuig	12 12 2	16 26 43.92	—3 42 48.8

The second normal place,—June 18.5; $a = 16h\ 24m\ 31.91s \pm 0.13s$; $\delta = -4^\circ\ 22'\ 9.5'' \pm 2.1''$.

From observations,

14.	June 22.	Leipzig	11 22 58	16 33 26.36	—1 49 8.3
15.	" 22.	Leipzig	12 2 0	16 33 29.88	—1 48 5.2
16.	" 22.	Göttingen	11 56 41	16 33 30.76	—1 48 0.3

The third normal place,—June 23.5; $a = 16h\ 35m\ 51.30s \pm 0.09s$; $\delta = -1^\circ\ 10'\ 12.7'' \pm 1.1''$.

These places containing the perihelion passage give the elements of orbit,

$$\begin{array}{rl} T & \text{June } 16.868927 \\ \omega & \left.\begin{array}{l} 15^\circ\ 20'\ \ 9.1'' \\ 245\ \ 11\ \ 18.9 \\ 17\ \ 32\ \ 29.4 \end{array}\right\}\ 1887.0 \\ \Omega & \\ i & \\ \log q & 0.144398 \end{array}$$

A comparison with elements previously published indicate these elements as favorable in a definitive determination of the orbit. FRANK H. BIGELOW.

Racine College, Sept. 20, 1887.

[We are sorry that Professor Bigelow's paper came just a little too late for our last issue.—ED].

Lake Forest University is now planning for a large astronomical observatory of its own. The trustees of that institution had some conference with the Chicago Astronomical Society concerning the removal of the instruments of Dearborn Observatory to Lake Forest. The latest report at hand is, that the Chicago Astronomical Society have decided to relocate Dearborn Observatory at Evanston, Ill., in consideration of the offer of the Northwestern University located at that place. It is also reported that Governor Ross, who is president of the Tribune Company, Chicago, and president of the Board of Trust of Lake Forest University, is the financial backing of its new observatory.

Bright Meteor.—Saturday evening, Sept. 21, at eight minutes past nine o'clock, I saw a fine meteor at Madison, N. J.,

shooting down from a point well up in eastern sky toward the northeastern horizon. Its color was of a delicate bluish tinge, leaving behind it sparks of a deep red hue. Its apparent size was greater and its light many times brighter than that of Venus. It left no train behind it, at least none visible to the naked eye. Its motion was swift, and the portion of its course which I saw was from near Beta Andromedæ, past Beta Persei (Algol), ending two or three degrees below a latter star, being a distance of about twenty-five degrees. JOHN H. EADIE.

Iowa College Observatory.—This growing college, located at Grinnell, Iowa, is building a new astronomical observatory and pushing it to completion rapidly. The building will be ready probably during the present month, for the 8-inch equatorial from the shops of the Clarks. Mr. Grinnell, the founder of the town, is furnishing the necessary funds.

Double Meteor.—We regret that Mr. Barnard's note of a double meteor came too late for June, and was inadvertently omitted from the last MESSENGER. It was seen May 12 at $8h$ $57m$ while he was observing with a low power on the 6-inch equatorial; it appeared double, moved slowly across the field, filling one degree. The components were about 8 magnitude, and distant one minute of arc and were moving eastward, the line joining them extending north and south. There was no change in brightness or relative position while crossing the field. The telescope pointing was

$$\text{R. A.} = 12h\ 20m$$
$$\text{Decl.} = -19^\circ$$

This is the first double meteor which Mr. Barnard has seen in the telescope.

Eclipse Expedition to Japan.—The letters by Mrs. Todd, member of the eclipse expedition to Japan, to *The Nation* (Sept. 1 and 22) from Shirakawa, Japan, concerning the preparations of the party to observe the total eclipse of Aug. 19, are profitable reading, although scarcely anything worthy of record was accomplished on account of unfavorable weather.

The Forum for September has two important articles on astronomical themes. "Great Telescopes" is the title of one by Professor C. A. Young, in which he gives a historical sketch of the growth of great telescopes, reflecting and refracting, both in America and in foreign lands. He also compares the merits of large and small telescopes, rather to the disadvantage of the larger both on account of their cost and disproportionate advantage in the various lines of astronomical work. The second article is by Professor Alexander Winchell, of Michigan University, on "Ignatius Donnelly's Comet." Professor Winchell evidently is not a convert to the new theory of earth's drift formation, nor does he like the scientific imagination of the writer of "Ragnarok" better than astronomers do those terrible comet collisions in earth's primordial times.

Corrections to Catalogue No. 6 of New Nebula discovered at the Warner Observatory.—In the list of errata to this catalogue in the *Astronomische Nachrichten*, No. 2798-99, Dr. Swift notes that Nos. 2 and 7 are identical with Nos. 277 and 303 in the Leander McCormick Observatory list, previously published in the *Astronomical Journal*, No. 152. It should be added that Nos. 1 and 18 are identical with Nos. 276 and 397 of the last named list.

No. 12 was discovered by Tempel. The place and description are given by him in the *Astronomische Nachrichten*, No. 2212.

No. 22 is probably identical with No. 5348 of Dreyer's Supplement to the General Catalogue. The difference in right ascension is 2.0*m* and in declination 2.6′, but the descriptions agree in stating that G. C. 965 is in the field.

This opportunity is taken of noting a correction to No. 98 of the Leander McCormick list in the *Astronomical Journal*, No. 146. Prof. Barnard kindly calls attention to the fact that he had published the place of this nebula some time previously in the *Astronomische Nachrichten*, No. 2588.

Leander McCormick Obs'y, Oct. 13, 1887. FRANK MULLER.

Dearborn Observatory.—The latest news at hand concerning the Dearborn Observatory, is that the Chicago Astronomical Society is under orders to move from the present site to the Northwestern University at Evanston, Ill., a few miles only from Chicago.

As far as known the arrangement is that the University shall erect suitable buildings for the instruments of the Society and complete the outfit of minor instruments, so that the observatory at its new site shall be fully equipped for general astronomical work. The Chicago Astronomical Society, we believe, is still to own its astronomical instruments. This is certainly a grand opportunity for the University, and it will doubtless be well improved under the continued directorship of Professor Hough.

Ann Arbor Observatory is to lose Mr. J. M. Schaeberle, widely and favorably known in connection with Detroit Observatory under Director M. W. Harrington.

In July last President Holden offered Mr. Schaeberle the position of Astronomer at the Lick Observatory. Mr. Schaeberle has accepted the position. It appears, however, that the Regents of the State University of California will not take official action in the matter until the observatory is turned over to the State. In the mean time Mr. Schaeberle expects to remain at Ann Arbor. The observatory will feel his loss.

Morrison Observatory.—Publication No. 1 of the Morrison Observatory of Glasgow, Mo., has been received. It contains a description of the observatory and instruments. The equatorial telescope has a clear aperture of 12¼ inches and the Meridian Circle telescope an object-glass of 6 inches aperture. The work of the observatory shown consists of measures of double stars, observations of the Transit of Mercury May 5-6, 1878, occultations, measures of the diameter of Mars, observations of the Red Spot on Jupiter, observations of Saturn, Uranus, comets and the new star in the nebula of Andromeda. The volume is a valuable one for the astronomical library.

Dearborn Observatory.—By the kindness of a friend and member of the Chicago Astronomical Society, a neat bound volume of the annual reports of the Board of Directors of the Chicago Astronomical Society, together with the report of the Director of the Dearborn Observatory for the years 1885 and 1886, was sent us promptly. As heretofore, Professor Hough has used the large equatorial on a few special subjects, viz.: difficult double stars, the planet Jupiter, and miscellaneous observations. Of Jupiter, Professor Hough says:

As in former years, the object of general interest is the great red spot.

The outline, shape and size of this remarkable object has remained without material change from the year 1879, when it was first observed here, until the present time. According to our observations, during the whole of this period it has shown a sharp and well-defined outline, and at no time has it coalesced or been joined to any belt in its proximity, as has been alleged by some observers.

During the year 1885, the middle of the spot was very much paler in color than the margins, causing it to appear as an elliptical ring. The ring-form has continued up to the present time. While the outline of the spot has remained very constant, the color has changed materially from year to year. During the past three years it has at times been very faint, so as barely to be visible.

The persistence of this object for so many years leads me to infer that the formerly-accepted theory, that the phenomena seen on the surface of the planet are atmospheric, is no longer tenable. The statement so often made in text-books, that in the course of a few days or months the whole aspect of the planet may be changed, is obviously erroneous.

The rotation period of Jupiter from the red spot has not materially changed during the past three years. The "mean" period, 1884-5, was 9*h* 55*m* 40.4*s*. Marth's ephemeris for the present year is based on a period of 9*h* 55*m* 40.6*s*. The mean correction to this ephemeris is now (May 1887) only about minus 7 minutes, indicating a slightly less value.

A number of equatorial white spots were systematically observed in 1886; but, owing probably to the low altitude of the planet, they have not been so conspicuous during the present opposition.

The oval white spots on the southern hemisphere of the

planet, 9″ south of the equator, have been systematically observed at every opposition during the past eight years. They are generally found in groups of three or more, but are rather difficult to observe. The rotation period deduced from them is nearly the same as from the great red spot.

These spots usually have a slow drift in longitude of about 0.5° daily in the direction of the planet's rotation, when referred to the great red spot; corresponding to a rotation period of 20 seconds less than the latter.

Under the appendix is found articles entitled, Motion of the Lunar Apsides by Professor Colbert, Catalogue of 209 New Double Stars, Nebulæ found at Dearborn Observatory, 1866-8, Description of the Printing Chronograph, and Observations of the Companion to Sirius.

Washburn Observatory, with Professor Asaph Hall as Consulting Director, and Professor George C. Comstock as Associate Director, confessedly is getting the cream of American astronomy for the daily sustenance of its scientific management. Western men can but be delighted at the willing approach of these eastern lights of the science. Congratulations to Washburn are certainly in order.

Mr. E E. Barnard, well known observer formerly at Nashville, Tenn., has been appointed to the position of Astronomer at Lick Observatory, Mt. Hamilton, California. This is another wise choice on the part of Professor Holden. Mr. Barnard is a young man of proved ability who has gained his skill as an observer and his knowledge of astronomy by the dint of hard work and this appointment is a just recognition of his ability.

Charles H. Rockwell, of Tarrytown, N. Y., has in hand an intensely interesting astronomical problem for thought and observation. Astronomers becoming aware of the accuracy of the Almucantar for latitude determinations have asked Mr. Rockwell to use his fine instrument to observe the moon when in apogee and in perigee to see if any systematic difference could be noticed in the latitude results while in these different positions. Mr. Rockwell proposes to continue these observa-

tions for two years, that he may have ample data for the discussion of the problem. This work will be followed with no common interest.

General Bibliography of Astronomy.—In June, 1887, Professors J. C. Houzeau and A. Lancaster, of Brussels, Belgium, published the first volume of their great work entitled "Bibliographie Générale de L'Astronomie." In 1882 the same authors published a collection of memoirs, which together make volume II in a series under the above title. The themes of the memoirs of the volume of 1882 are: The History and Study of Astronomy; Astronomical Biographies, Spherical Astronomy; Theoretical Astronomy; Celestial Mechanics; Physical Astronomy, Practical Astronomy; Monographs on the principal members of the Solar System and Stellar Astronomy. In volume II there is much of interest both for the amateur and for the practical astronomer. Fuller reference to this important work will be given in the future.

Elements and Ephemeris of the Olbers Comet.—Normal places were formed on the dates, August 28, 31, September 6, 15, 18, 23, by means of Ginzel's elements and the perihelion time given in SIDEREAL MESSENGER, No. 57-58 and through the differential cöefficients corrections were obtained to these elements as follows:

$$\begin{aligned}
\Delta \pi &= +\ 5'\ 55.8'' \\
\Delta \Omega &= -\ 1\ \ 29.7 \\
\Delta i &= +\ 1\ \ 19.6 \\
\Delta T &= +\ 0.045223da \\
\Delta q &= -\ 0.0021360 \\
\Delta e &= -\ 0.0006647
\end{aligned}$$

giving as the new elements,

$$\begin{aligned}
T &= 1887, \text{ Oct. } 8.549199 \text{ Gr. M. T.} \\
\left.\begin{aligned}
\omega &= 65^\circ\ 24'\ 41.6'' \\
\Omega &= 84\ \ 29\ \ 54.5 \\
i &= 44\ \ 34\ \ 53.9
\end{aligned}\right\} & \ 1887.0 \\
\log q &= 0.078619 \\
\log e &= 9.968420
\end{aligned}$$

From these elements the following ephemeris results, Ephemeris for Greenwich midnight (1887.0).

	A. R.			Dec.		lg. r	lg. Δ	L
Oct. 24	13	15	23	+ 20	42.8	0.0872	0.2810	1.50
28		31	54	19	13.6	0.0919	0.2850	....
Nov. 1	13	47	45	17	43.0	0.0975	0.2897	1.38
5	14	2	57	16	12.2	0.1039	0.2949	....
9		17	29	14	42.1	0.1110	0.3006	1.24
13		31	24	13	13.5	0.1188	0.3066	....
17		44	42	11	47.2	0.1270	0.3128	1.08
21	14	57	25	10	23.6	0.1358	0.3192	....
25	15	9	35	9	3.1	0.1449	0.3257	0.94
29		21	15	7	46.0	0.1543	0.3321	....
Dec. 3		32	25	6	32.6	0.1639	0.3385	0.82
7		43	7	5	22.8	0.1737	0.3447	....
11	15	53	23	4	16.8	0.1836	0.3506	0.70
15	16	3	13	3	14.5	0.1936	0.3564	....
19	16	12	40	+ 2	15.9	0.2036	0.3618	0.61

Unit of light, Aug. 27, 1887.

Dudley Observatory, Oct. 19, 1887. H. V. EGBERT.

The Orbit of Σ 1757, by J. E. Gore, as reprint from the "Monthly Notices," is on our table. The elements given in the Monthly Notices of November, 1886, failed to satisfy recent observations, hence the new determination, as follows:

$P = 276.92$ years $\qquad \Omega = 87° 36'$

$T = 1791.98$ A. D. $\qquad \lambda = 185° 23'$

$e = 0.4498 \qquad a = 2.05''$

$\gamma = 40° 56' \qquad \mu = +1.30°$

New Minor Planet (269) was discovered by Palisa at Vienna Sept. 21, having position, Sept. 21.5201 G. M. T.,

$a = 23h\ 15m\ 55.7s$

$\delta = -7°\ 15'\ 25''$ Twelfth magnitude.

New Minor Planet (270) was discovered by Peters. Oct. 8.5534 G. M. T., its position was,

$a = 1h\ 17m\ 3s$

$\delta = +12°\ 26'$ Twelfth magnitude.

New Minor Planet (271) (?) was discovered by Knorre, with position, Oct. 16.5218,

$a = 1h\ 12m\ 32.8s$

$\delta = +12°\ 1'\ 32''$ Eleventh magnitude.

The last two are probably the same asteroid.